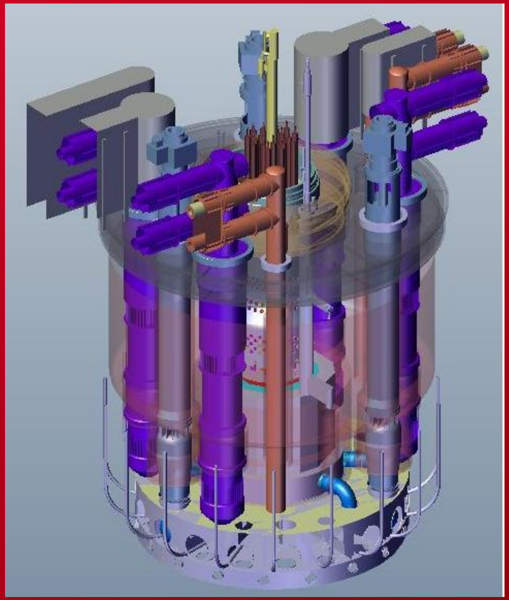
DE LA RECHERCHE À L'INDUSTRIE



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INTERNATIONAL CONFERENCE ON FAST REACTORS AND RELATED FUEL CYCLES: SAFE TECHNOLOGIES AND SUSTAINABLE SCENARIOS (FR13)

THE FRENCH FAST REACTOR PROGRAM - INNOVATIONS IN SUPPORT TO HIGHER STANDARDS

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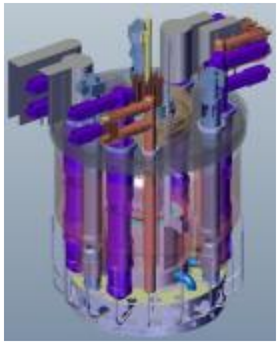
INTRODUCTION

- **Fast neutron reactors have a large potential as sustainable energy source.**
- **Among the fast reactor systems, the sodium cooled reactor has the most comprehensive technological basis as result of the experience gained from decades of worldwide operation of several experimental, prototype and commercial size reactors.**
- **Innovations are needed to further enhance safety and improve reliability and operability.**
- **In France, a medium size (600 MWe) power demonstrator named ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration) is being developed.**
- **Deriving from the feedback of experience, very high levels of requirements have been set for the ASTRID reactor.**

THE FRENCH FAST REACTOR PROGRAM - ASTRID

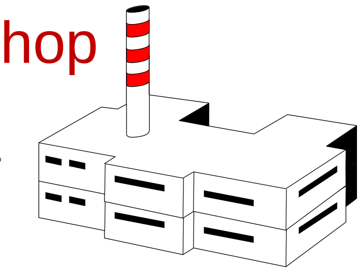
- **Rapsodie – Phénix – Superphénix reactors but also SPX2, RNR-1500, EFR projects**
- **CEA focuses on two technologies :**
  - Based on the accumulated operating experience of more than 400 reactor.years, the SFR shows the best potential to reach 4th generation criteria for industrial deployment in the middle of the 21st century, or even earlier if needed. → ASTRID reactor.
  - As a long term alternative, the gas-cooled fast neutron reactor (GFR) needs the development of a refractory fuel composed of uranium-plutonium carbide fuel pellets with silicon carbide ceramics cladding. The fuel represents the key element of the safety demonstration in case of loss of heat removal systems or in case of depressurization of the primary circuit. The feasibility is still to be proven. → ALLEGRO project.

THE ASTRID PROGRAM



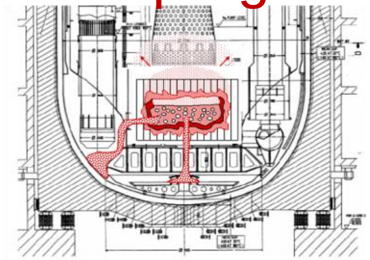
- **ASTRID design studies**
  - Integrated Technology Demonstrator 600 MW(e)
  - 4th generation reactor
  - Irradiation tool

- **Core fabrication workshop**
  - MOX fuel
  - A few tons per year



- **Full scale component testing**
  - Large test sodium loops
  - Refurbishment of zero power reactor MASURCA

- **Severe accidents experimental program**

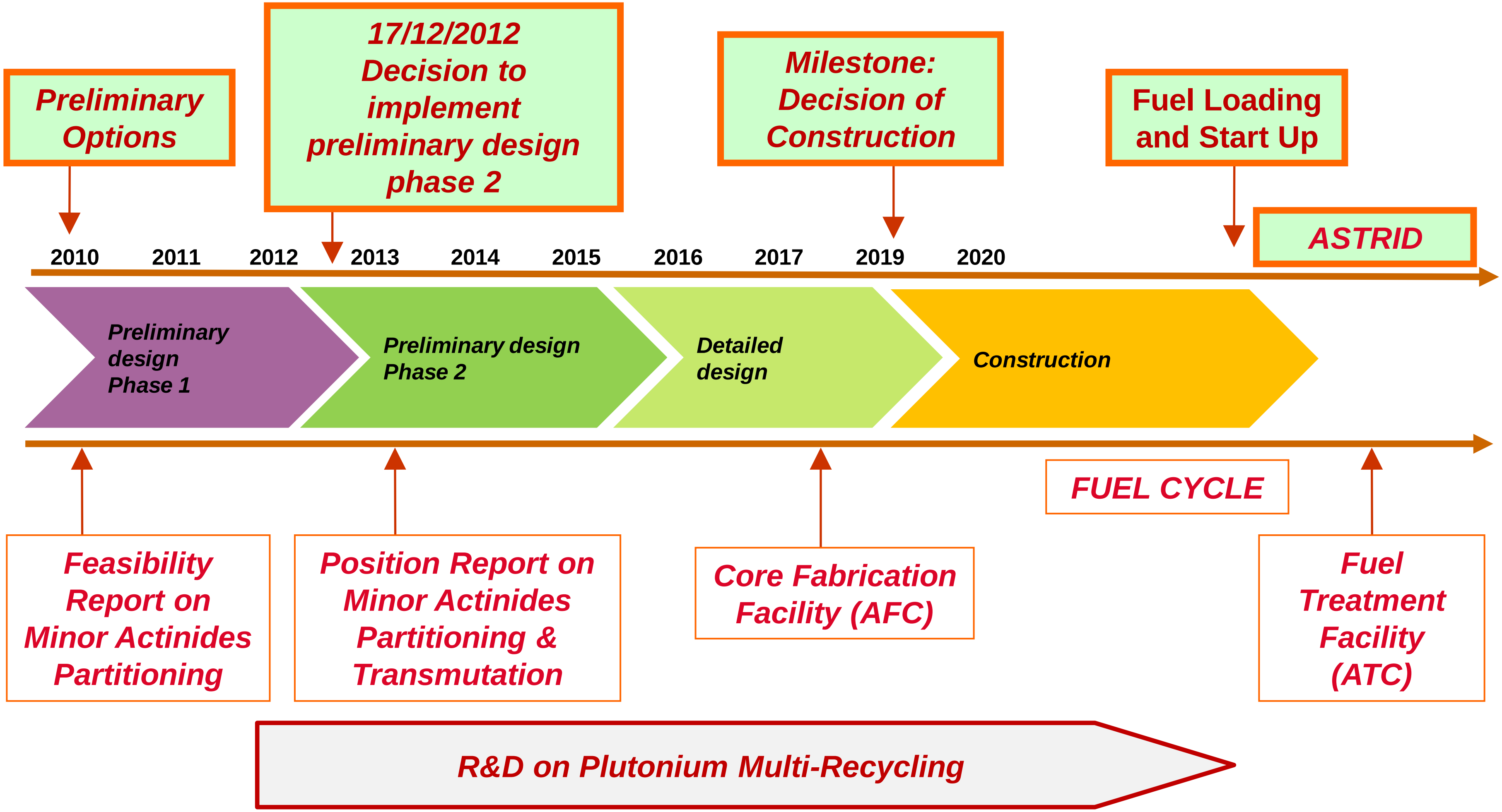


- **Feasibility of experimental fabrication of minor actinides bearing fuel**

+ R&D

(Including fuel cycle)

ASTRID SCHEDULE



HIGHER STANDARDS IN TERMS OF SAFETY AND OPERABILITY

- **ASTRID is seen as a full Generation IV prototype reactor, with strong improvements on safety and operability.**
- **Its safety level shall be at least as good as current 3rd generation reactors, with advances on core and sodium-related issues, and taking into account the necessary lessons learnt from the Fukushima accident.**
- **On the availability side, the reactor shall reach a high load factor after a learning period.**

[1] Le Coz, P., CEA, “The ASTRID Project : Status and Future Prospects”, FR13, Paris France 4-7 March 2013; Paper CN-199-261

[2] Lo Pinto, P., CEA, “Safety orientations during ASTRID conceptual design phase”, FR13, Paris France 4-7 March 2013; Paper CN-199-267

[3] “WENRA Statement on Safety Objectives for New Nuclear Power Plants”, November 2010

[4] “Safety Objectives for New Power Reactors - Study by WENRA Reactor Harmonization Working Group”, December 2009

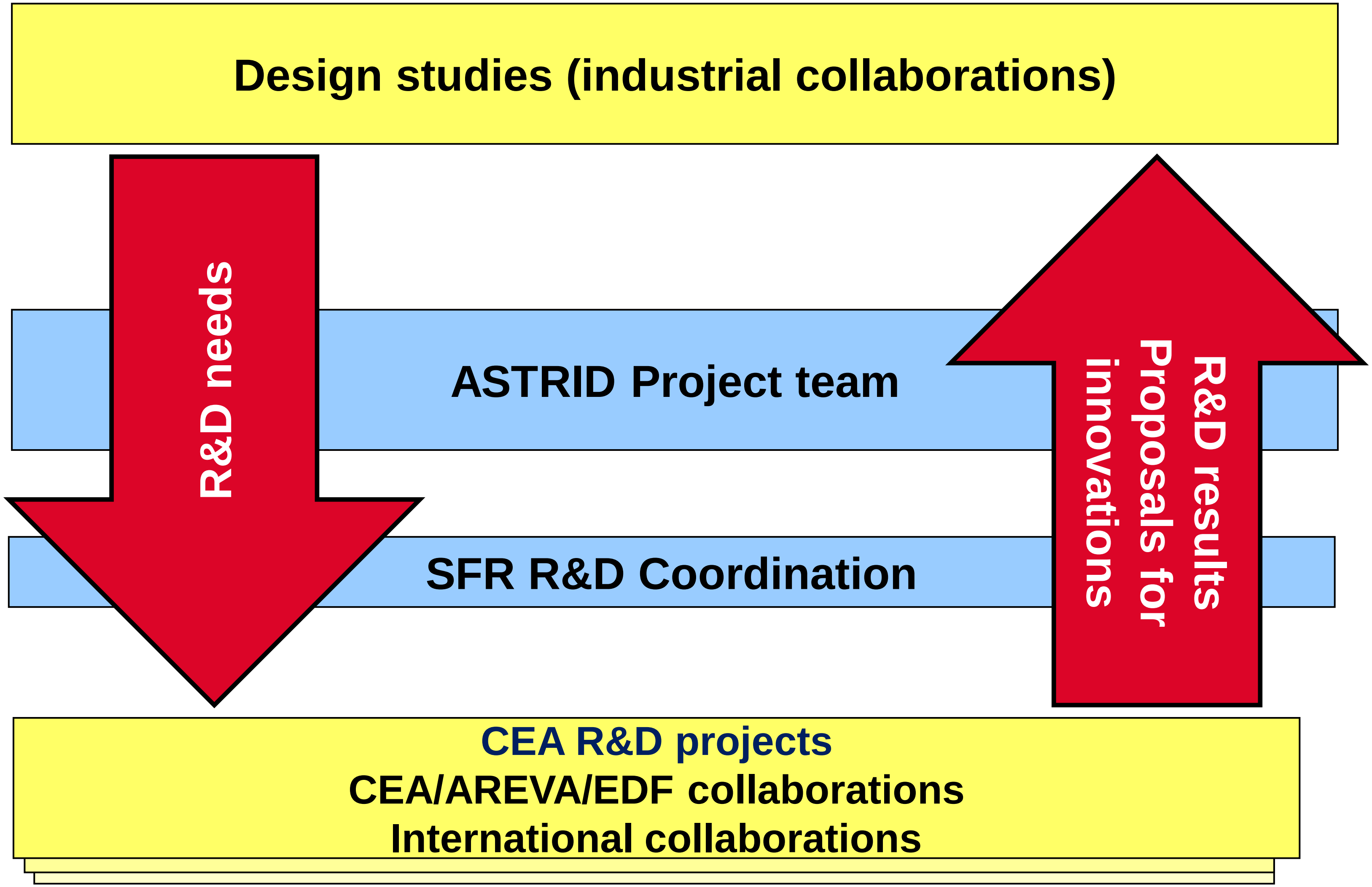
DERIVING THE R&D FROM THE FEEDBACK OF EXPERIENCE 1/2

Feedback of previous SFRs	R&D directions	ASTRID Orientations
Core Sodium voiding reactivity → Safety	Optimization of core design to improve natural behavior during abnormal transients. Exploration of heterogeneous cores	CFV core (Patented in 2010): innovative approach, very low or negative overall sodium voiding reactivity Better natural behavior of the core, for instance in case of loss of flow (e.g. due to loss of supply power)
Sodium-Water interaction → Safety - Availability	Modular Steam Generators Inverted Steam Generators (sodium in tubes) Gas Power Conversion System (nitrogen in place of steam/water)	Limitation of total released energy in case of sodium-water interaction Limitation of wastage propagation Design studies conducted by ALSTOM. No show stopper.

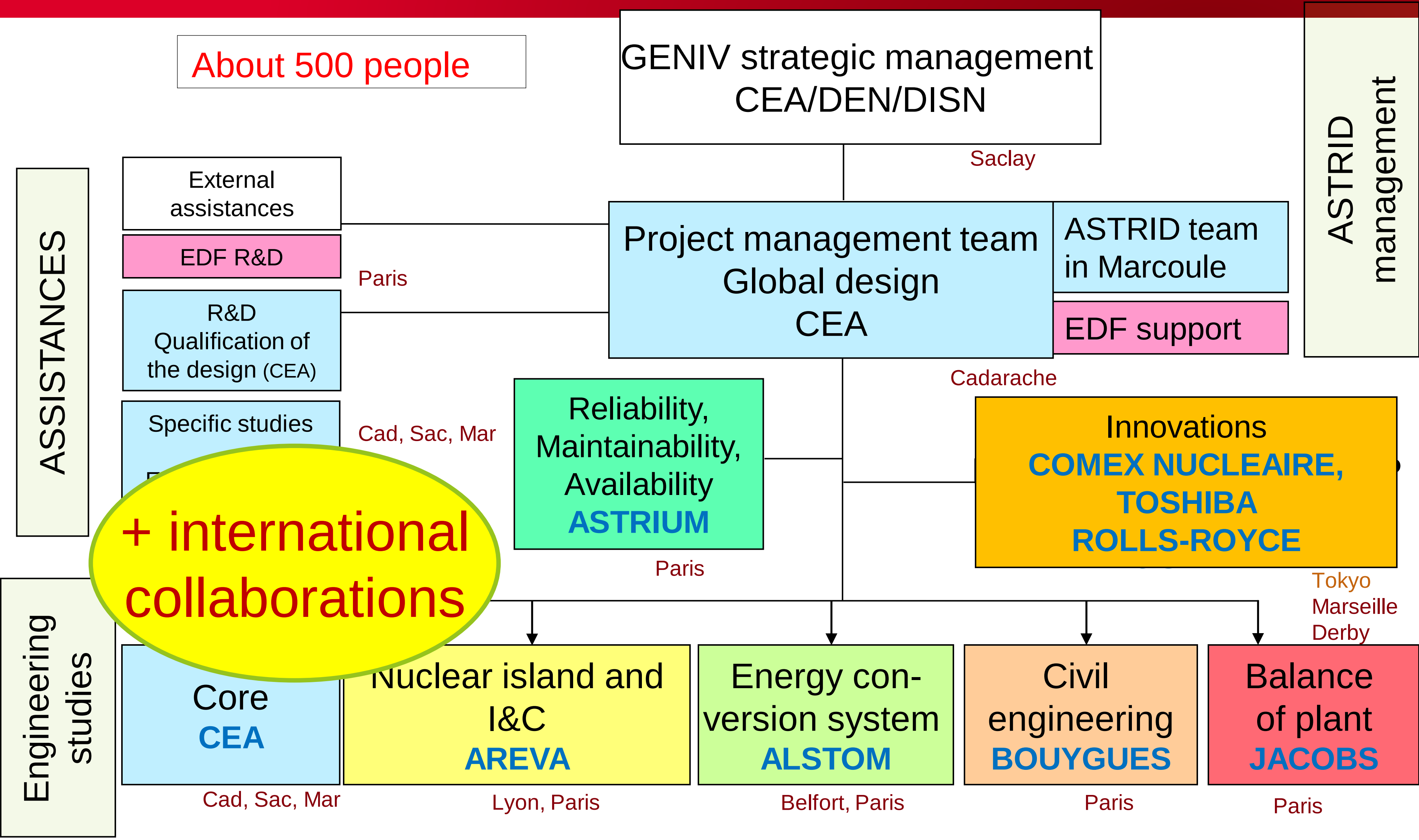
DERIVING THE R&D FROM THE FEEDBACK OF EXPERIENCE 2/2

Feedback of previous SFRs	R&D directions	ASTRID Orientations
Sodium fire **→ Safety**	Innovative Sodium leak detection systems R&D on Sodium aerosols	Improving detection (Patent of detection system integrated in the heat insulator) Close containment (inert gas + restriction of available oxygen)
Severe accidents **→ Safety**	Core catcher Research on corium and sodium-corium interaction	Core catcher. Several possible locations (in vessel, ex-vessel or between the two vessels).
Decay heat removal **→ Safety**	Reactor vessel auxiliary cooling system (scaling rules)	Combination of proved Decay Heat Removal systems and Vessel Natural Air draft cooling
In-Service Inspection and Repair **→ Safety – Availability**	Simplification of primary system design ISI&R taken into account from the design stage New techniques : Acoustic Detection, Laser, CRDS Signal processing Ultrasound at high temperature, High temperature fission chambers, Optical Fibers, Flow meters for subassembly Remote handling for inspection or repair Under-sodium viewing	

DRIVING THE R&D BY THE PROJECT



ASTRID PROJECT INDUSTRIAL ORGANISATION



BENEFITS OF INDUSTRIAL COLLABORATIONS

- **Better than in a commercial relationship, the collaborative scheme allows more bottom-up R&D and innovations that are proposed by the industrial partners to CEA. For instance, strong improvements in the gas energy conversion system were proposed by ALSTOM, feedback of EPR construction will be integrated by BOUYGUES into the civil engineering studies etc.**
- **The objective of the coming years will be to expand this collaborative circle of industrial partners.**
- **The industrial partners help CEA to verify that ASTRID will meet the expectations in terms of operability, since they usually do business with customers to whom reliability, availability and maintainability are essential.**

CONCLUSION

- **From the experience of ASTRID first phase of conceptual design studies (2010-2012), two remarks can be made:**
  - Higher requirements in safety and operability lead to higher costs that cannot be fully recovered by advances in technology. This puts additional pressure on the next phases of the design to optimize the design and to keep the costs to the minimum.
  - There is a clear link between the level of safety that can be achieved and the maturity of the technology, i.e. the experience accumulated in R&D, design, construction, operation and decommissioning of past reactors. In the field of fast neutron reactors, this gives a strong advantage to the sodium technology, because strengths and weaknesses are well mastered.
- **Meeting the high requirements set for ASTRID and serving R&D needs of innovative options will require increased industrial and international collaboration.**